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ORIGINAL RESEARCH

THE RELIABILITY AND CONCURRENT VALIDITY OF MEASUREMENTS USED TO QUANTIFY LUMBAR SPINE MOBILITY: AN ANALYSIS OF AN IPHONE® APPLICATION AND GRAVITY BASED INCLINOMETRY

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ABSTRACT

Purpose/Aim: This purpose of this study was to investigate the reliability, minimal detectable change (MDC), and concurrent validity of active spinal mobility measurements using a gravity-based bubble inclinometer and iPhone® application.

Materials/Methods: Two investigators each used a bubble inclinometer and an iPhone® with inclinometer application to measure total thoracolumbo-pelvic flexion, isolated lumbar flexion, total thoracolumbo-pelvic extension, and thoracolumbar lateral flexion in 30 asymptomatic participants using a blinded repeated measures design.

Results: The procedures used in this investigation for measuring spinal mobility yielded good intrarater and interrater reliability with Intraclass Correlation Coefficients (ICC) for bubble inclinometry ≥ 0.81 and the iPhone® ≥ 0.80. The MDC_{90} for the interrater analysis ranged from 4˚ to 9˚. The concurrent validity between bubble inclinometry and the iPhone® application was good with ICC values of ≥ 0.86. The 95% level of agreement indicates that although these measuring instruments are equivalent individual differences of up to 18˚ may exist when using these devices interchangeably.

Conclusions: The bubble inclinometer and iPhone® possess good intrarater and interrater reliability as well as concurrent validity when strict measurement procedures are adhered to. This study provides preliminary evidence to suggest that smart phone applications may offer clinical utility comparable to inclinometry for quantifying spinal mobility. Clinicians should be aware of the potential disagreement when using these devices interchangeably.

Key Words: Inclinometer, range of motion, smart phone, spine.

***Level of Evidence*:** 2b (Observational study of reliability)

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INTRODUCTION

According to the Guide to Physical Therapist Practice, the examination of joint integrity and mobility is necessary in order to select appropriate physical therapy interventions.[1] Moreover; recognizing mobility impairments may assist clinicians in making diagnoses, measuring improvements or deteriorations in mobility, and in determining limitations in functional activities of daily living.[1,2] Therefore, it is essential for clinicians to have reliable and valid measurement instruments in order to objectively and accurately monitor disease progression and outcomes.

The examination of spinal range of motion (ROM) may be accomplished through visual observation or by using a number of measurement instruments including: motion analysis, goniometry, linear measures, and inclinometry.[3] The method or instrument a clinician uses may vary and is often dependent on accessibility of the instruments to the clinician, cost, educational dogma, and the specific movements being evaluated. Goniometry has been used widely due to its portability and low cost.[4,5] A limitation of goniometry is that it requires the clinician to use both hands, and locate anatomical landmarks, making stabilization of the patient's position more difficult, thus increasing the risk of error by inaccurate reading or incorrect placement.[4] Additionally, goniometry does not allow the differentiation between the pelvic and lumbar contributions to spinal mobility. Inclinometry is an alternative to goniometry that incorporates the use of constant gravity as a reference point.[5,6] Bubble inclinometers are portable, lightweight, inexpensive, and require training similar to that of goniometry. Disadvantages of inclinometry may be their accessibility in clinics and familiarity with measurement procedures by clinicians. A study by Samo et al[7] found that the source of greatest variability of inclinometric measurements may be caused by the examiner and/or technical errors. Procedural errors such as misplacement of the inclinometer at a region distant to the landmark, failure to maintain constant pressure during movement, and technical errors, such as holding the inclinometer slightly off plumb, could give inaccurate readings.[7] From an accessibility perspective, smart phones may be a practical alternative to inclinometry. In an unpublished questionnaire performed by one of the authors (MP) in 2011 of third year doctor of physical therapy students, 26 of 48 surveyed reported owning a third or fourth generation iPhone® with an additional 20 owning a comparable smart phone. Smart phones such as the iPhone® and those that use the Android™ operating system have free applications such as the iHandy® Level that provide the capacity to convert the phone into an inclinometer using a built-in tilt sensitive system.

With regard to the lumbar spine, a body of evidence exists to support the use of inclinometry for quantifying ROM. Gravity-based inclinometry is reported to possess both good reliability and criterion validity for measuring lumbar ROM. Saur et al[8] reported that a gravity-based inclinometer is a valid instrument for quantifying isolated lumbar flexion and extension ROM when compared with radiographic measurements ($r \geq 0.75$) in a population with low back pain. In the aforementioned study, the interrater reliability for isolated lumbar flexion was good ($r = 0.88$) compared to extension ($r = 0.42$), however lateral flexion was not assessed. Mayer et al[9] used a computerized double and single inclinometer technique in order to measure pelvic flexion among both symptomatic and asymptomatic participants and reported identical mean measurement angles. Additionally, the study investigated the criterion validity of lumbar flexion and extension ROM measurements and concluded that there was no significant difference ($p < 0.01$) between inclinometric and radiographic measurements.[9] The authors, however, did not report reliability or validity coefficients for their measurement procedures. Ng et al[10] studied the intrarater reliability of isolated lumbar ROM in an asymptomatic cohort using an inclinometric procedure that restricted pelvic ROM. The procedures yielded good intrarater reliability for lumbar flexion ($r = 0.87$), extension ($r = 0.92$), and lateral flexion ($r \geq 0.94$); however the use of a standing metal frame to restrict pelvic mobility limits the clinical utility of the techniques.[10] Waddell et al[11] investigated the interrater reliability of total thoracolumbo-pelvic flexion, isolated flexion, total thoracolumbo-pelvic extension, isolated extension, as well as lateral flexion, in a mixed cohort of asymptomatic, as well as subjects with low back pain. In the aforementioned study an electronic inclinometer was used and the intraclass correlation coefficients (ICC) were reported to range from 0.87-0.95, suggesting good reliability. Waddell et al[11] did report exclud-

ing isolated measurements of lumbar extension as a result of poor reproducibility. Although it appears that inclinometric measurements of lumbar mobility have been sufficiently investigated, minimal detectable change (MDC) values and 95% levels of agreement have not been reported limiting the clinician's ability to interpret error and change scores.

Despite the growing popularity of smart phones in recent years, this evolution of technology has not been studied as a clinical instrument for measuring lumbar ROM. Research to determine the reliability of smart phone applications is necessary prior to implementation of such equipment in the clinical setting. Moreover, whether smart phone applications can be used interchangeably with currently accepted measurement devices has yet to be investigated. Given the lack of available research investigating the reliability and validity of smart phone applications, it is unclear as to whether these devices can be used with confidence in the clinical setting.

Therefore, the purpose of this study was to investigate the intrarater and interrater reliability of spinal ROM measurements of total thoracolumbo-pelvic flexion, total thoracolumbo-pelvic extension, isolated lumbar flexion, and thoracolumbar lateral flexion using both an iPhone© with iHandy© Level application, as well as a bubble inclinometer. Additionally, the authors sought to investigate the MDC_{90} and concurrent validity of the iPhone® and a bubble inclinometer for each of the aforementioned measurements.

DESIGN

Participants

Thirty (30) asymptomatic adult participants, 12 men and 18 women, were recruited from a local university setting. Inclusion criteria consisted of being greater than or equal to 18-years of age, having the ability to read and speak English as necessary to comprehend forms and procedures, the ability to stand and ambulate without an assistive device, and the absence of low back pain or lower extremity pain at the time of data collection. Participants who met study requirements were provided with an informed consent document approved by the Institutional Review Board at Nova Southeastern University and all questions were answered to their satisfaction prior to commencing data collection. Additionally, participants completed a questionnaire to report age, height, body mass, and arm dominance.

Instruments

A standard plinth, new Baseline® bubble inclinometer (Figure 1) (model 12-1056, Fabrication Enterprises; White Plains, New York), and iPhone® model 4 (iPhone® is a trademark of Apple Inc, Cupertino, California) with iHandy© level (iHandySoft, Inc, New York, New York) application were used for this investigation. The iHandy® level application (Figure 2) is a free application with a visual display similar to that of a digital inclinometer in regard to numeric size. The application uses the iPhone's® built-in accelerometer and a digital display to display the angle measured. There is no reported accuracy of this application by the manufacturer.

Procedures

Following completion of paperwork and consent, individuals who agreed to participate were brought into a private testing laboratory where they performed a standardized warm-up supervised by the raters who were all third year doctoral physical therapy students. The warm-up required approximately two minutes to complete and consisted of supine pelvic rotations with the knees bent 90 degrees (˚). For the warm-up participants were instructed to rhythmically rotate

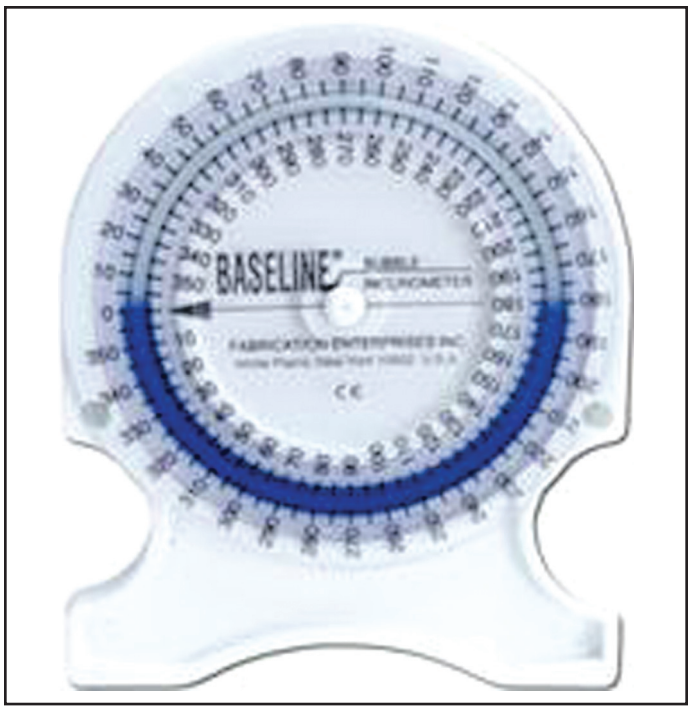

Figure 1. *Baseline® bubble inclinometer.*

Figure 2. *iPhone® with screen illustrating the iHandy© level application. *Power-on/off side, **Port connection side.*

30-45˚ to the left and right for the two minute duration. Each participant was required to perform the same warm-up for consistency; however, to our knowledge there is no benefit or detriment to performing the warm-up. The aforementioned exercise was chosen as it primarily required lumbar rotation, therefore would not influence the tested movement planes.

Following the warm-up, participants were requested to stand in a comfortable position that required no perceived effort with their arms at their sides while their skin was marked approximately at the T12 and S1 spinous processes using a dry-erase marker. The iliac crest was used as a baseline landmark for L4-L5. Once L4-5 was identified, the investigator palpated down to the S1 spinous process, whereas T12 was identified by locating the 12th rib and following it to the spinous process. These landmarks were used for placement of the inclinometer as described by Waddell et al.[11] Prior to taking each of the 5 measurements (thoracolumbo-pelvic flexion, isolated lumbar flexion, thoracolumbo-pelvic extension, right lateral flexion, left lateral flexion); each participant observed the investigator performing one repetition and then performed each motion for one practice repetition from a comfortable start position in standing. The purpose of the demonstration and practice trial was to familiarize participants with the requested motions. Following the practice trial, participants performed each of the five active ROM (AROM) movements in consecutive order (thoracolumbo-pelvic flexion, isolated lumbar flexion, thoracolumbo-pelvic extension, right and left thoracolumbar lateral flexion). Measurements were not randomized as the purpose of the study was to evaluate measurement reproducibility, which requires a consistent physiological status. For each active repetition, participants were requested to move to the limits of their end-range and maintain the position while the angle was obtained with the bubble inclinometer and iPhone® consecutively. *See supplemental video content for inclinometric measurement procedures*. Verbal cues were provided strictly as necessary to ensure proper form during the measurement and to ensure movement was performed to the available end-range. Once the measurement was performed and recorded by Rater A, participants returned to the start position and the measurement was repeated. Each measurement was obtained twice with the iPhone® application and twice with the bubble inclinometer before proceeding to the next movement plane. The mean value of the two measurements from each instrument was used for analysis. The raters were blinded to the results, as an independent third person (Rater C) with similar experience in spinal AROM measurements recorded all data. Once Rater A completed all 5 measurements, participants were given a ten-minute rest break followed by an additional two-minute warm-up session prior to repeating all motions with Rater B. The interrater reliability and concurrent validity component of the investigation was completed at this time. The second session (24-48 hours later) consisted of a two-minute warm up followed by Rater A obtaining all measurements twice with each device to complete the intrarater reliability component of the investigation. For consistency among instrument placement, Rater A was responsible for marking all participants in both sessions.

The procedures for measuring thoracolumbo-pelvic flexion, isolated lumbar flexion, thoracolumbo-pelvic extension, and thoracolumbar lateral flexion followed guidelines established by Waddell et al,[11] and have previously been reported in the literature to have good intrarater reliability with r ≥ 0.87. Unlike inclinometry which has a 360° measurement capability and simply requires a zeroing of the instrument prior to movement, the iPhone® requires additional calculations as described below.

Total thoracolumbo-pelvic (sacral) flexion AROM was assessed with the participant standing with their feet shoulder width apart and arms resting at their side. The inclinometer was placed at the level of T12-L1 and set to zero upon contact with the landmark. Participants' were then asked to bend forward attempting to touch their hands to the floor while maintaining knee extension. Once movement ceased, the measurement was recorded by Rater C and transferred to the data collection sheet. To repeat this measurement using the iPhone® application, the power on-off side was placed on the participant at approximately T12-L1 with screen facing laterally. When calculating total flexion with the iPhone® application, the starting angle at T12-L1 was recorded prior to beginning the motion and added to the final angle recorded at the end of the motion. For example, if upon placement of iPhone® an angle of 10°(extension from a vertical reference) was present and the final angle was 90° an angle of 100° was recorded as the device travelled from 10° to 0° to 90°. Although not present in the current study, if an individual had a start position anterior to the 0° point (relative kyphosis) then the start measurement would be subtracted from the final measurement as the device did not travel past zero during the motion and only the actual motion is measured.

Isolated lumbar flexion AROM was assessed with the participant standing with their feet shoulder width apart and arms resting at their side. Isolated flexion involves two measurements, the first at T12-L1, and the second at S1-S2. For our investigation, the value obtained from total flexion was utilized as our T12-L1 measurement. The inclinometer was zeroed at S1-S2 and the angle at the end-range of forward flexion was recorded. To calculate isolated flexion with an inclinometer, the measurement from S1-S2 was subtracted from T12-L1 (total flexion measurement). Using the power on-off side of the iPhone® on each landmark stated above, the starting angle was added to the angle recorded at the end of the motion for both T12-L1 and S1-S2. The result at S1-S2 was then subtracted from the result at T12-L1 (total flexion measurement) to provide isolated lumbar flexion.

Total thoracolumbo-pelvic (sacral) extension AROM was assessed with the participant standing with their feet shoulder width apart with their hands placed on their low back at the level of L4-L5. The rater holding the instrument placed their hand in front of the participant's thighs to prevent motion at the knees as well as for safety. The inclinometer was placed at T12-L1 and zeroed prior to beginning the motion. The participants were then asked to bend backward as far as possible while maintaining knee extension as the angle was recorded. When using the iPhone® for measuring extension, the port-connection side was placed at T12-L1. The starting angle was recorded and subtracted from the final angle at the end of the motion.

Thoracolumbar lateral flexion AROM was assessed with the participant standing with feet shoulder width apart and arms resting at their side. The inclinometer was zeroed on a level surface (using a bubble level) and placed at T9-T12 prior to beginning the motion. The participants were asked to slide their hand down the side of the leg as far as possible while maintaining trunk and head facing forward and both feet on the ground. Once the motion ceased or the participant could not continue without compromising form (forward flexing or bending ipsilateral knee) the measurement angle was obtained and recorded. The iPhone® was placed flat at T9-T12 with the power side pointed toward the side of flexion and the screen facing the examiner. Both the inclinometer and iPhone® started from zero on the participant prior to side flexing and the final number was recorded at the end of the motion.

The measurements required approximately 30-minutes from the initiation of the warm-up to completion for session 1 and 10 minutes for session 2. Raters remained blinded to both their results as well as the other rater's results throughout the investigation.

STATISTICAL METHODS

Data analysis was performed using SPSS version 15.0 for Windows statistical program. Descriptive data

including mean measurement angles with standard deviations (SD) were calculated for each session. The reliability of all measurements was determined by the intraclass correlation coefficient (ICC) Model 3, k for the intrarater component of analysis and Model 2, k for the interrater analysis. The mean value from each testing session was used for the analysis. Model 3, k was used for the intrarater analysis because Rater B was the only tester of interest. Model 2, k was used for the interrater analysis to determine if the instrument of choice can be used with confidence and reliability among equally trained clinicians.[4,5] The minimal detectable change (MDC_{90}) was calculated using the formula: $MDC_{90} = 1.65*SEM*\sqrt{2}$ to determine the magnitude of change that would exceed the threshold of measurement error at 90% confidence level.[4] MDC_{90} values were rounded to the nearest degree to reflect the smallest unit of measurement available on the gravity based inclinometer.

An ICC Model 3, k was used in the concurrent reliability analysis to determine if both methods of measurement analysis produced comparable results. ICC value interpretations were based on guidelines established by Portney and Watkins.[4] The 95% limits of agreement (LOA) were calculated using the formula: 95% LOA = mean difference +/- 2SD.[4]

RESULTS

The mean and standard deviation (SD) for the participants' age, body mass, and height were 25.6 (2.1) years, 70 (13.7) kg, and 172 (10.9) cm respectively. The right arm was dominant in 29 of the 30 participants. Descriptive data, including the mean and SD for each of the five measurements are presented in Table 1. Good intrarater reliability was found with both instruments with all measurements ranging from, ICC (3, k) = 0.80-0.97. Measurement data from the intrarater reliability analysis including the ICC with 95% confidence interval (CI) are presented in Table 2. Interrater analysis suggested good reliability for all measurements with both instruments ranging from, ICC (2, k) = 0.81-0.98. Measurement data from the interrater reliability analysis including the ICC and 95% CI as well as the MDC_{90} are presented in Table 3. The concurrent validity between bubble inclinometry and iPhone® measurements was good for both raters with ICC (3, k) ranging from 0.86-0.98 (Table 4). The 95% levels of agreement (Table 5) suggests that iPhone® measurements of spinal AROM are equivalent to the bubble inclinometer as the ranges crossed the zero point for each measurement, however individual differences may range from being 18˚ greater to 16˚ less than a gravity based bubble inclinometer.

DISCUSSION

When adhering to the procedures outlined in this investigation, measurements taken using the bubble inclinometer and iPhone® application possessed good intrarater and interrater reliability. With regard to measurements taken using the bubble inclinometer, the reliability results are consistent with previous research which has reported good ICC values when utilizing similar measurement procedures.[1] Unfortunately no data is available with which to compare the current findings when using the iPhone®. The MDC_{90} for the interrater analysis for both instruments indicated that changes of 4˚ to 9˚ are required to be 90% certain that the change is not due to intertrial variability or measurement error. No previous research exists to compare this data.

Table 1. *Descriptive Measurement Data.*

Instrument	Rater	Total Thoracolumar Pelvic Flexion Mean° (SD)	Isolated Lumbar Flexion Mean° (SD)	Total Thoracolumbar Pelvic Extension Mean° (SD)	R. Thoracolumbar Lateral Flexion Mean° (SD)	L. Thoracolumbar Lateral Flexion Mean° (SD)
iPhone®	Rater A	107(18)	50(11)	27(7)	32(7)	29(6)
	Rater B	108(18)	49(9)	28(10)	31(7)	30(7)
Bubble Inclinometer	Rater A	107(18)	45(9)	28(8)	30(6)	28(5)
	Rater B	107(17)	46(8)	28(10)	31(7)	30(7)

Abbreviations: *SD, Standard Deviation; R., right; L, left;*

Table 2. *Intrarater Reliability of iPhone® and Bubble Inclinometer for Rater A.*

Instruments	Total Thoracolumbar-Pelvic Flexion ICC (95% CI)	Isolated Lumbar Flexion ICC (95% CI)	Total Thoracolumbar Pelvic Extension ICC (95% CI)	R Thoracolumbar Lateral Flexion ICC (95% CI)	L Thoracolumbar Lateral Flexion ICC (95% CI)
iPhone®	0.97(0.93-0.98)	0.88(0.75-0.94)	0.80(0.58-0.90)	0.82(0.61-0.91)	0.84(0.67-0.92)
Bubble Inclinometer	0.96(0.91-0.98)	0.83(0.64-0.92)	0.88(0.74-0.94)	0.88(0.74-0.94)	0.83(0.64-0.92)

Abbreviations: *ICC, Intraclass Coefficient (3,K); CI, Confidence Interval*

Table 3. *Interrater Reliability and MDC90 of iPhone® and Bubble Inclinometer.*

Instruments	Total Thoracolumbar-Pelvic Flexion ICC (95% CI) MDC_{90}	Isolated Lumbar Flexion ICC (95% CI) MDC_{90}	Total Thoracolumbar-Pelvic Extension ICC (95% CI) MDC_{90}	R Thoracolumbar Lateral Flexion ICC (95% CI) MDC_{90}	L Thoracolumbar Lateral Flexion ICC (95% CI) MDC_{90}
iPhone®	0.98(0.95-0.99) 6°	0.88(0.76-0.95) 8°	0.81(0.60-0.91) 9°	0.93(0.86-0.97) 4°	0.90(0.77-0.96) 4°
Bubble Inclinometer	0.97(0.93-0.99) 7°	0.81(0.60-0.91) 9°	0.91(0.81-0.96) 6°	0.88(0.74-0.95) 5°	0.84(0.65-0.93) 6°

Abbreviations: *ICC, Intraclass Correlation Coefficient (2,k); CI, Confidence Interval; MDC_{90}, Minimal detectable change at the 90% confidence interval and rounded to the nearest degree.*

With regard to concurrent validity, measurements with a bubble inclinometer were found to be comparable to those taken with the iHandy© Level application on the iPhone® with ICC values ≥ 0.86. The mean values of the bubble inclinometer were slightly lower when compared with the iPhone® mean values by both raters for all measurements except total thoracolumbo-pelvic extension for Rater A (Table 1). There was no identifiable systematic error in technique that could explain the differences. One consideration may be that the measurements taken by the devices differ due to their shape as the iPhone® is completely linear.

When comparing instruments such as the Baseline bubble inclinometer and iPhone® application, it is important to consider limitations to both instruments. The inclinometer uses a fixed vertical reference point realized by gravity, thus is stable provided the zero point is accurately calibrated and established. Other issues that warrant discussion are the method of placement and the calculations required when using iPhone® application. The placement on the subject for the two instruments is consistent however there are more contact points (port vs. power side) to consider when using the iPhone®. Moreover, clinicians may be reluctant to use their personal phone as it requires phone to skin contact. Lastly, the procedures for using the iPhone® maybe considered inconvenient and potentially expose the clinician to errors. Specifically, understanding the placement of the instrument (power vs. port side) is essential when performing various measurements to prevent the screen from rotating at 45°. Moreover, the various calculations required

Table 4. *Concurrent Validity of iPhone® and Bubble Inclinometer.*

Measurement	Rater	ICC (95% CI)
Total Thoracolumbar-Pelvic Flexion	A	0.98 (0.97-0.99)
	B	0.97(0.93-0.98)
Isolated Lumbar Flexion	A	0.87(0.45-0.95)
	B	0.86(0.64-0.94)
Thoracolumbar-Pelvic Extension	A	0.91(0.81-0.96)
	B	0.89(0.77-0.95)
Right Thoracolumbar Lateral Flexion	A	0.94(0.80-0.98)
	B	0.95(0.90-0.98)
Left Thoracolumbar Lateral Flexion	A	0.91(0.82-0.96)
	B	0.96(0.92-0.98)

Abbreviations: *ICC, Intraclass Correlation Coefficient (3,k); CI, Confidence Interval*

Table 5. *95% Level of Agreement (iPhone® –gravity based inclinometer).*

	95% Level of Agreement
Total Thoracolumbar-Pelvic Flexion	iPhone® + 15°, - 15°
Isolated Lumbar Flexion	iPhone® + 18°, - 7°
Total Thoracolumbar-Pelvic Extension	iPhone® + 12°, -16°
Right Thoracolumbar Lateral Flexion	iPhone® + 12°, - 6°
Left Thoracolumbar Lateral Flexion	iPhone® +10°, - 8°

of the iPhone® application as each motion is measured requires a different mathematic equation unlike the inclinometer which offers a direct reading.

To the knowledge of the authors, this study was the first to analyze the concurrent validity of bubble inclinometry and iPhone® application measurements of thoracolumbo-pelvic mobility. Due to the lack of research in this area, a comparison between the current study and previous research cannot be made. However, this study does set the groundwork for further research in this area in order to evaluate the interchangeability of smart phone applications with other commonly used measurement tools.

Limitations

When interpreting the reliability values in our investigation, one must recognize that the consistency of AROM in individuals who are asymptomatic may not correlate with those who have lumbar pathology. This

investigation required participants to hold their end-range for approximately 5-10 seconds, that allowed measurements to be performed which may not have been possible in a symptomatic cohort. Lastly, the participants in this investigation consisted of a young, college-aged population (mean age = 26). Therefore, our results may not necessarily be generalized to a sub-group with increasing or decreasing age. Additionally, the mean values obtained in this study may be less or more than that obtained in a clinical setting or reported in examination textbooks. The difference in values is most likely the result of adherence to strict measurement planes in this investigation and the use of healthy asymptomatic college-aged participants. Although the researchers had limited clinical experience, they were intentionally following a research protocol that was practiced, thus experience with the procedures may have had an effect on the mobility values as well as the reliability.

CONCLUSION

Physical therapists have a variety of options to measure ROM and often times it is based on familiarity and convenience. A bubble inclinometer is one device that has good reliability and criterion validity; however it is not available in every clinic. With increasing usage of smart phones by newer graduates and the accessibility of free measuring applications, these devices can potentially become a tool for measuring ROM in the clinic. Clinicians not opposed to using their personal phones for patient contact, as well as performing the calculations required for obtaining ROM measurements with the iPhone® may find it to be an efficient and accurate option to utilize during measurements of ROM.

This investigation is the first of its kind to evaluate the reliability and concurrent validity of iPhone® measurements of lumbar AROM. When using the measurement procedures outlined in this investigation, the iHandy© Level application on the iPhone® is both reliable and comparable to bubble inclinometry. Although good reliability and concurrent validity statistics were present, one should recognize the potential ranges of disagreement between the two measurements instruments used in this study. Moreover, clinicians and researchers should consider the MDC_{90} when interpreting change scores.

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